Modelling the Development of Rifted Continental Margins - *"Time travel by computer"*

geo*facts*

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Introduction

In the search for oil and gas reserves, it is vital that geologists understand the history of the formation of geological features. While it is possible, in some cases, to measure many present-day features directly, there is a need to understand how they have formed over the million of years of geological time.

For this reason, geophysicists at the Atlantic Geoscience Centre of the Geological Survey of Canada (GSC) are using computer models to help them understand the formation and history of rifted continental margins off Canada's east coast.

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What are "continental margins"?

The thin crust of the earth comes in two forms: oceanic and continental (Figure 1). Oceanic crust is young and thin (about 5 to 10 kilometres), and is formed from the intrusion of molten rock at the mid-ocean ridges. Continental crust is older and thicker (up to 40 kilometres), having been formed from numerous mountain-building episodes throughout the Earth's

history. The regions along the edge of the continents, where the crust becomes thinner and meets oceanic crust, are known as continental margins.

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Why "rifted"?

There are several types of continental margins; only one is featured here. Rifted continental margins are those formed when a continent splits apart (rifts), allowing new oceanic crust to form in the gap. The eastern margin of Canada is a rifted continental margin. Canada was joined to Africa and Europe before the opening of the Atlantic Ocean about 200 million years ago. This is illustrated by rocks found in the southern part of Nova Scotia which are like those found in Morocco.

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Why is this study important?

When continents split apart, the continental margins on either side of the new ocean become sites of sediment accumulation. Rivers carrying sediment from across the continent reach the sea at the continental margin and deposit the sediment. Over millions of years, several kilometres of sediment can build up, which results in a sedimentary basin.

Because oil and gas can be found in sedimentary basins, oil companies are extremely interested in Canada's rifted continental margins. Major oil and gas reserves have been identified off Nova Scotia and Newfoundland. Research by the GSC into the formation and evolution of rifted continental margins and their sedimentary basins supports the industry.

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What is meant by "modelling"?

Since geophysicists cannot observe directly events that have taken place over millions of years, they have to find indirect methods to investigate. One approach is to set up a conceptual model of the development of a rifted continental margin, and measure how well it can predict the geological characteristics of the present-day continental margin. While the "model" is usually in the geophysicists's mind, some researchers have been known to make them from clay and sand.

Researchers do not expect the conceptual models to explain every aspect of continental margin development. In fact, they generally learn as much from the mismatch between the model and reality as they do from the parts of the model that seem to be correct. The information gained by making mistakes can be used to correct and improve the model so that increasingly, it describes the real thing.

Such conceptual models, however, have several limitations for those trying to understand rifted continental margins. A major limitation is that they do not allow for detailed predictions about the development of sedimentary basins. For this reason, geophysicists at the Atlantic Geoscience Centre have begun recently to use computers to create numerical models. Using highly sophisticated computer programs that simulate the development of a

continental margin, the numerical models-in similar fashion to the conceptual models-provide a means of asking "what if?"questions, to see how the answers affect the modelled continental margin.

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How is a numerical model constructed?

First the geophysicists have to decide how they wish to look at the continental margin. To keep it simple, they usually look at only two dimensions-a cross-section. For purposes of the model, they have to assume that things do not change along the length of the continental margin, though of course, in the real world, they do. They then define a starting condition: for example, the characteristics of the continental crust before rifting. Next, they define the properties of the rocks making up the crust. Fox example, they might divide the model into layers with different mechanical properties (the rate at which rocks will crumble when extended) and thermal properties. Values for temperature and the rate of sediment accumulation also have to be defined. The computer then takes all these values at the starting point and calculates how the margin develops over a series of time period. The result is a picture of how the continental margin changes through time.

The important step, then is to compare the model results with the real continental margin. This can be done because of a large amount of geophysical data on the continental margins that has been collected by the GSC for the past 30 years. Based on these comparisons, the model can then predict features such as the shape of the sedimentary basin and the thickness of the crust beneath it. Deep seismic reflection, seismic refraction and gravity survey data can provide the direct observations for use in comparison to the model.

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What use is made of the results of the numerical models?

Petroleum geologists need to know how continental margins and sedimentary basins have developed, because it is critical to the formation of oil and gas reserves. For them to form in a sedimentary basin, certain temperatures and pressure conditions have to be met. These conditions, which depend largely on the subsidence history of the basin and the heat flow through it, can be determined from the numerical models. A study of this nature is underway for two east coast basins-the Scotian Basin off Nova Scotia and the Jeanne d'Arc Basin off Newfoundland, where the Hibernia oil field was discovered.

A second reason for developing the models is to help geophysicists understand the formation of the Atlantic Ocean. One major advantage is that, based on this knowledge, they can compare one continental margin with its equivalent on the other side of the ocean. Such a study of conjugate margins can then provide petroleum geologists with new targets for oil and gas exploration.

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Photos: (Not presently available)

Scientists from the Bedford Institute of Oceanography deploy ocean bottom seismometers to conduct reflective surveys.

Ships such as the Hudson from the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, are used to deploy ocean bottom seismographs.

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Figures: (Not presently available)

Figure 1: The schematic illustrates the evolution of a rifted continental margin. As the continent splits, new oceanic crust (shown as dark shading) forms in the gap.

Results of a numerical model off the coast of North America (lower). The model fits reasonably well with the data measured from seismic surveys and oil wells (upper).

Scientists use numerical models to help them predict oil generation zones within the sedimentary basins.

Reconstructions of the North Central Atlantic at 200 and 53 million years age. Rifting caused the continents to move apart.

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